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Analysis on the development and policy of solar PV power in China

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ABSTRACT

China's PV industry has developed rapidly in recent years due to the dramatic demand from the world market. In contrast, until 2010 China's domestic PV market has been very small due to lack of sufficient incentives in the country to promote domestic PV deployment. However, since early 2009 many incentives have been implemented in China. The paper makes an analysis on China's solar PV incentive policies, particularly the national FIT scheme. Policy recommendations are made with regard to the promotion of the domestic solar PV market, including the construction of an effective national FIT scheme, the imposition of renewable portfolio system as well as the establishment of sound technical and administration standards for the grid-connection of PV systems. The paper contributes to the academic literature over China's solar PV power policy.

Contents

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1. Introduction

Solar power resources are abundant, widely available, one of the major renewable energy sources that have the greatest development potential. The major solar power technology in world usage is solar photovoltaic (PV), in which the sun's light is directly converted into electricity by means of a silicon-based material. Solar PV power generation is clean, safe, convenient, and highly efficient. As global energy shortages and environmental pollution have become increasingly prominent, solar PV power has received worldwide attention. Countries such as Germany, Italy, Japan, Spain and the USA have implemented many incentives to support solar PV market development. As a consequence, the global total solar PV market has seen a remarkable growth, with a total capacity increasing from 4 GW in 2004 to 70 GW in 2011 and an average annual growth rate of over 58%, the fastest of all renewable technologies during the period from the end of 2006 through 2011. For the first time ever, in 2011 solar PV accounted for more new electricity generating capacity in the European Union than did any other technology [1]. PV power is now a significant part of Europe's electricity mix, producing 2% of the demand in the EU and roughly 4% of peak demand. In Italy, PV covers 5% of the electricity [2].

Thanks to the dramatic demand from the world market, during the period of the 11th Five-year Plan (FYP, 2006–2010), China's PV industry developed rapidly and became one of the few industries that could compete globally. China has been the largest PV manufacturing nation since 2008 when it became the largest producer of solar panels in the world, shipping 26,000 MW peak of PV panels, which was roughly one-third of worldwide total cell shipments. It is also interesting to note that 90–95% of these products has been exported to Europe and North America. On the other hand, China's domestic PV market has been very small due to insufficient incentives to promote domestic PV deployment in the country.

However, ever since the financial crisis in 2008, the Chinese manufacturers have greatly suffered from the shrinking foreign market, due to the aggressive cut of incentives by Germany and other European countries, and the anti-dumping and countervailing investigation against Chinese PV products initiated by the United States and the EU since Oct. 2011. It was in this context that the Chinese government, recognizing the need to support this critical growth industry with domestic demand to reduce dependency on overseas markets. Ever since March 2009, particularly during 2011–2012, a series of incentives, including direct subsidies for solar PV installations, a national FIT scheme, among others, have been implemented by the government. In response to these incentives, China's domestic PV market has seen a steady growth, with its cumulative installed capacity rising from140 MW in 2008 to 300 MW in 2009, and to 800 MW in 2010, then surging to 3300 MW in 2011, representing a share of 0.89%, 1.231% and 2.05% and 4.95% of the world total respectively [3–4].

Literature review shows that studies on China's renewable energy policy mostly focus on China's wind power policy, which is quite understandable, as over the past years the Chinese government has attached much importance to its wind power development. Some studies on China's PV power development largely center on China's solar PV development status and prospects [5–8] or a particular PV program in China [9]. And a few studies examine China's solar PV policies [10–11]. To our knowledge, rare studies make a comprehensive analysis on China's solar PV policies, particularly on policies implemented during 2011–2012.

The purpose of this paper is to make an effort to fill this gap. It contributes to the academic literature over China's solar PV power policies. The paper is organized as follows: Section 2 provides an overview of China's solar PV development; Section 3 makes a review on China's solar PV policies, particularly the FIT scheme implemented in 2011; policy challenges are discussed in Section 4; and Section 5 makes policy recommendations, followed by concluding remarks in Section 6.

2. Overview of China's PV development

This section provides an overview of China's solar PV development from the perspectives of solar PV industry development, solar PV power market development and solar PV power application in the country.

2.1. Solar PV industry development in China

Solar PV industry chain involves several stages: (1) purify silicon, shape it into ingots and then slice the ingots into thin wafers; (2) cut the thin wafers into desired dimensions and shapes to make solar cells; (3) connect and laminate the solar cells to form a solar module; (4) assemble the solar module in array and combined with electrical components to make a PV system (Fig. 1).

The PV development in China started in 1958 and began to enter into application stage in the 1970s. It was not actually industrialized until the middle of the 1980s when two single crystalline silicon solar cell production lines were introduced and the large-scale utilization period came. Since 1993, the output of domestic crystalline silicon solar cells soared by 20–30% annually [13].

Due to the dramatical increasing demand for PV by European countries since 2004, Germany in particular, China's PV production has experienced dramatic growth and has moved towards a huge solar production ramp on all fronts of the domestic supply chain, from polysilicon, wafers to cells and modules. During the 11th Five Year Plan (11th FYP), the production of solar cell had

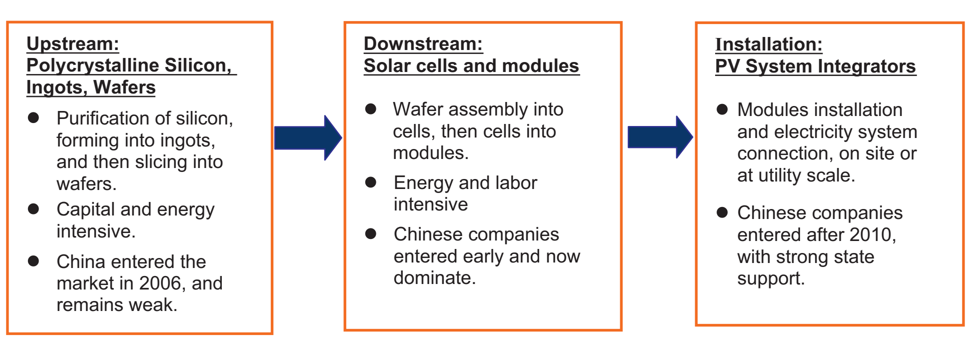


Fig. 1. Solar PV industry chain.
Source: [12]

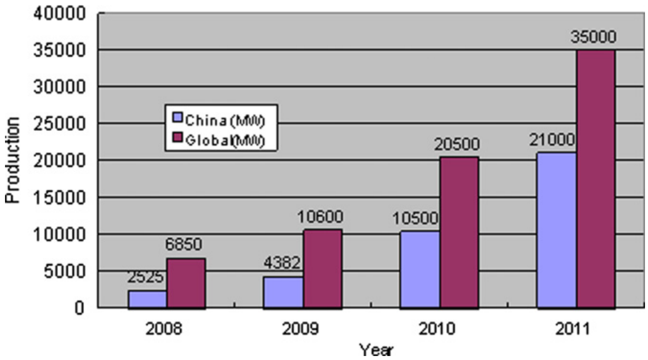


Fig. 2. Production of PV cell during 2008–2011: China and global (MW).
Source: [15]

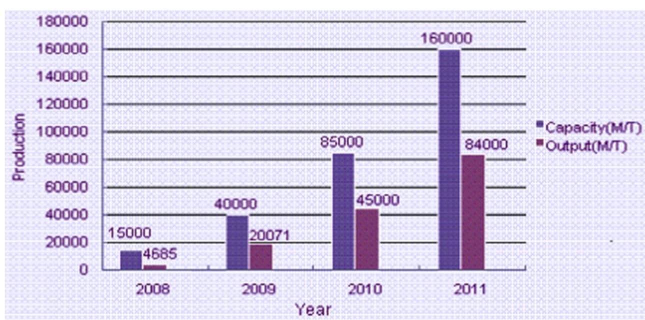


Fig. 3. Production of polysilicon in China during 2008–2011.
Source: [15]

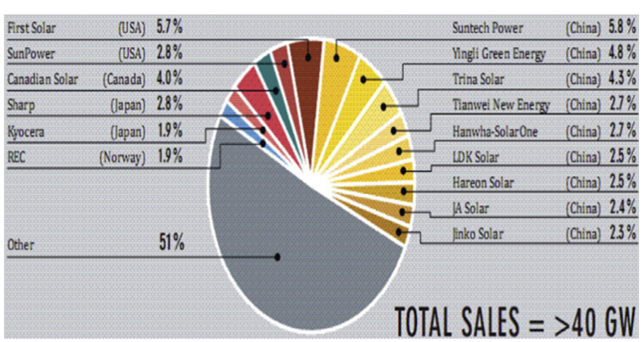


Fig. 4. Market shares of top 15 solar PV module manufacturers, 2011.
Source: [1]

developed at a growth rate of more than 100% and had ranked the first in the world for five consecutive years and crystalline silicon cells accounted for more than 95% of total solar cell production [14]. In 2007, China took the world's number one position in solar cell manufacturing with a total production of over 1 GW [11]. In 2011, China manufactured 21 GW of solar cells (Fig. 2), representing 60% of the global total production, to secure its leading position. The export value of solar cell this year reached USD 22.67 billion, a share of 60% of the global market. The production of polysilicon also saw a steady growth, amounting to 84,000 M/T in 2011 (Fig. 3), ranking the first in the world. Out of the top fifteen solar PV module manufacturers in the world, nine were Chinese companies which took a share of 30% in the world (Fig. 4) [15].

Along with the increasing output, the prices of polysilicon, wafer, silicon cell and module cell have been declining steadily.

Table 1
Share of China's annual and cumulative installation in the world (2005–2011).
Source: [4,11].

Year	Annual installation (MW)			Cumulative installation (MW)		
	China	World	China's share	China	World	China's share
2005	7.9		%	70	5400	1.31%
2006	10	1600	0.6%	80	7000	1.15%
2007	20	2500	0.8%	100	9500	1.05%
2008	40	6500	0.62%	140	16,000	0.89%
2009	160	7000	2.29%	300	23,000	1.31%
2010	500	17,000	2.94%	800	40,000	2.05%
2011	2500	27,400	9.12%	3300	66,700	4.95%

And China's solar PV production technology and the quality of solar cell have improved year by year. In particular, leading enterprises have made rapid progress in terms of conversion efficiency. At present, the conversion rates for monocrystalline silicon solar cells, polycrystalline silicon solar cells and thin-film and other new types of cells have reached 17–19%,15–17% and 6–8% respectively [14].

2.2. *Solar PV power market development in China*

Historically, the high cost of PV has restricted China's PV market growth. For many years, China's PV power market only centered on off-grid rural electrification projects, which only allowed for a very small amount of installations. However, the cost of PV has experienced sharp decline since 2009, and the past two years have seen some important developments in China's policies for PV and domestic PV market. In response to the introduction of a national feed-in tariff (FIT), the PV market installation in China reached a record high of 2.5 gigawatts (GW)in 2011, accounting for 9.12% of the world total in the year and bringing China's cumulative capacity to 3.3 GW, representing 4.95% of the global cumulative installed capacity (Table 1).

2.3. *Solar PV power application in China*

Solar PV power in China is applied in five sectors: off-grid solar PV in remote and rural areas; off-grid solar PV for telecommunications, meteorology, transportation and other industries; off-grid solar PV for lights, chargers and other commercial products; on-grid building solar PV which consists of integrated solar PV (BIPV) and building attached PV (BAPV); and large-scale (utility-scale) solar PV (Table 2). Before 2008, the off-grid solar PV in rural areas which provided an economical and sustainable option for meeting energy needs of remote rural households was the biggest market for solar PV power application in China as shown in Table 3, while on-grid solar PV took a very small fraction, for example, the share of on-grid solar PV in 2007 was only 11% of the total in the country [16].

However, thanks to the *Rooftop Subsidy Program* and *Golden Sun Demonstration Program* (for more information about the two programs, see the next section) initiated by the government in 2009, on-grid solar PV has developed rapidly since 2008, soaring to 99.2% in 2011 (Table 3).

3. Government incentive policies for solar PV power development

The solar PV development in China is closely related to the government's incentive policies. These include the Renewable

Table 2
China's solar PV market sector in 2011.
Source: [15,18].

	Market sector	Annual (MW)	Share	Cumulative (MW)	Share
Off-grid	Rural electrification	10	0.8%	82.5	5.4%
	Telecommunications and Industry use	5		48	
	solar PV commercial product	5		47.5	
On-grid	Building solar PV (BIPV and BAPV)	480	99.2%	730	94.6%
	Large-scale solar PV	2000		2392	
Total		2500	100%	3300	100%

Table 3
Share of off-grid and on-grid solar PV in China, 2004–2011.
Source: [17].

	Off-grid (MW)	Share	On-grid (MW)	Share	Annual (MW)	Cumulative (MW)
2004	8.8	88%	1.2	12%	10	62.1
2005	7.4	93.7%	1.5	6.3%	7.9	70
2006	9	90%	1	10%	10	80
2007	17.8	89%	2.2	11%	20	100
2008	19	90.5%	21	9.5%	40	140
2009	18	12.7%	142	87.3%	160	300
2010	25	5.3%	475	94.7%	500	800
2011	20	0.8%	2480	99.2%	2500	3300

Energy Law (2006) and relevant renewable energy policies (2006–2008), the Brightness program (1996), the Township Electrification Program (2002), the Rooftop Subsidy Program (2009), the Golden Sun Demonstration Program (2009), the PV Concession Program (2009), the most recent policies—the national Feed-in tariff (FIT) scheme (2011), the 12th Five Year Plan for Renewable Energy Development (2012) as well as the free connection service policy (2012).

3.1. *The renewable energy law and relevant renewable energy policies*

In 2005, China promulgated the *Renewable Energy Law*, which became effective on January 1, 2006 and was amended in 2009. By establishing five key mechanisms, the *law* created for the first time a national framework for the promotion of renewable energy development in China, Pursuant to the *law*, a series of renewable energy policies were issued. These include the *Provisional Administrative Measure on Pricing and Cost Sharing for Renewable Energy Power Generation* (2006), the *Tentative Management Method for Renewable Energy Development Special Fund* (2006), the *medium-and Long-term Renewable Energy Development Plan* (2007) and the 11*th Five-year Plan of Renewable Energy Development* (2008), among others.

The five key mechanisms established by the *law* are: (1) national targets for the development of renewable energy, which signifies that the government ensures a certain market scale and is crucial in directing investment; (2) a mandatory connection and purchase policy, by which grid companies are required to sign an agreement with renewable electricity generators in their jurisdiction to purchase all of the electricity generated from the generators, and provide grid connection services; (3) an on-grid electricity price for renewables, akin to a national feed-in tariff system, which pays renewable electricity generators a fixed, additional amount for each kilo-watt hour of electricity generated, above the wholesale electricity price for desulfurized coal-fired power; and (4) cost sharing mechanism—the cost of renewable energy generation and grid connection is divided amongst utilities and electricity end users, which is supported by a surcharge on electricity sales; (5) The Renewable Energy Development Special Fund, which offers additional financial support for activities such as science and technology research for renewables, standard setting, pilot projects, rural utilization of renewables, and the renewable resource assessments [19].

3.2. *The Brightness and Township Electrification Program*

The Brightness and Township Electrification Programs were the major driving force for solar PV market expansion in China in the late 1990s and early 2000s. In 1996, China's former State Planning Commission formulated and put forward plans for the *Brightness Program*. The aim of the program was to use PV modules and wind power systems to provide power for daily needs to the population of 23 million in China without access to electricity. The program targeted to provide this populace with a capacity averaging 100 W per person, at that time equivalent to China's overall average per capital installed power generation capacity. According to estimates, the total investment in equipment and services needed to achieve the project goals is about RMB 10 billion. Implementation is to focus on the provinces of Western China, with special support given to Xinjiang, Inner Mongolia, Gansu, Qinghai, and Tibet.

In 2002, in order to meet the power needs of public utilities and residents of un-electrified townships in remote, border regions of Western China, the National Development and Reform Commission (NDRC) initiated its *Township Electrification Program*. Of the 1065 towns included in the program, 688 were targeted for the construction of solar PV power stations, with a total installed capacity of 20 MW. Since the initiation of the project, the great majority of solar PV stations have been constructed and are now generating power. The total investment for the program is RMB 4.7 billion (of which RMB 2.96 billion is provided by Government bonds). The *Township Electrification Program* represents the first time that the Chinese government has used stand-alone renewable energy power generation systems on a large scale to resolve the electricity needs of un-electrified areas. The program has realized a transition from pilots and experiments in the use of stand-alone renewable energy power systems for resolving rural electrification needs to actual projects and implementation. Meanwhile, the program has, to a large extent, stimulated the rapid development of China's solar PV industry. China's capacity for production of PV modules has increased by ten times in a few years [20].

3.3. *The Rooftop Subsidy Program and Golden Sun Demonstration Program*

In order to wean the country's solar PV industry off dependence on overseas markets amid mounting trade frictions with

the USA and the EU, the Chinese government has rolled out measures to boost its domestic solar market. Two national solar subsidy programs—the Rooftop Subsidy Program and the Golden Sun Demonstration Program were initiated in 2009.

In March 2009, the Ministry of Finance (MOF) and the Ministry of Housing and Urban-Rural Development of China (MOHURD) announced the Solar Roofs Program, which provides upfront subsidy of RMB 15/W for rooftop systems and RMB 20/W for BIPV systems while the expense is covered by the Renewable Energy Development Special Fund. The program provides a subsidy of 50% of the bidding price for the supply of critical components such as grid-connected PV converters, crystalline silicon module, lead acid storage battery. It requires that the scale of a solar PV project be no less than 50 kW; and the generation efficiency of monosilicon PV products, polysillicon PV products, and amorphous silicon PV products exceed 16%, 14%, and 6% respectively [15].

In July 2009, the MOF, the Ministry of Science and Technology (MOST) and the National Energy Administration (NEA) initiated the second national solar subsidy program—the *Golden Sun Demonstration Program*, which supports more than 500 MW solar PV projects within two to three years. The program provides 50% of the total cost for on-grid systems and 70% of the total cost for off-grid systems. It requires the system size to be no less than 300 kW. For on-grid systems, on-site consumption is encouraged. Excess electricity could be sold to the utility at the local tariff of desulfurized coal generation (Fig. 5).

As of 2012, both programs have gone through four phases. The approved capacity of solar building projects (BIPV and BAPV projects) under the two programs totals 551.2 MW (Table 4). And 455 projects in total have been approved under the Golden Sun Demonstration Program, with a total capacity of 2872 MW (Table 5). These two subsidy programs clearly demonstrate China's determination to support the adoption of solar PV.

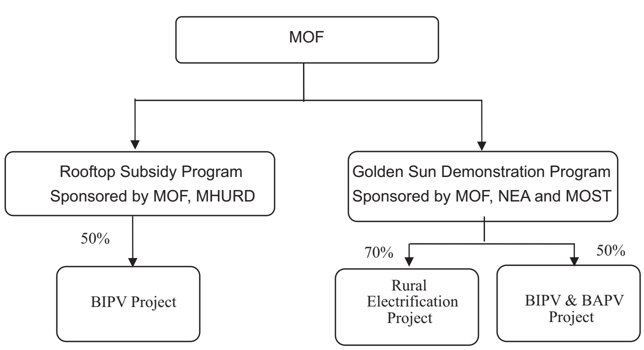


Fig. 5. Rooftop subsidy program and golden sun demonstration program in China.

Table 4
Solar PV building projects in China.
Source: [15,18].

Phase	Year	Approved projects	Approved capacity (MW)	Subsidy (RMB/W)	
				BIPV	BAPV
I	2009	111	91	20	15
II	2010	99	90.2	17	13
III	2011	106	120	12	—
IV	2012	—	250	9	7.5
Total		—	551.2	48	—

Table 5
Golden sun demonstration program.
Source: [15,18].

Phase	Year	Approved projects	Approved capacity (MW)	Subsidy (RMB/W)	
				Solar PV building	Off-grid
I	2009	98	201	14.5	20
II	2010	50	272	11.5	16
III	2011	140	690	C-Si: 9.0, a-Si: 8.5	
IV	2012	167	1709	5.5	> 7.0
Total		455	2872	—	—

3.4. The Solar PV Concession Program

Since 2009, the Chinese government has sponsored two rounds of public tender for solar powered projects. In March 2009, the NEA organized the first public bidding for the 10 MW project in Dunhuang city, Gansu Province, and then approved a on-grid price of RMB 1.09/kWh. In June 2010, the NEA initiated a second round of public tender for concession solar power projects. At the end of this tender, 13 projects consisting of 60 MW in inner Mongolia, 60 MW in Xinjiang, 60 MW in Gansu, 50 MW in Qinghai, 30 MW in Ningxia and 20 MW in Shanxi, etc. were announced with an aggregate capacity of 280 MW. While the successful bidders were required to complete the construction in 24 months, they would have an exclusive right to operate the plant for 25 years with a on-grid price. In October 2010, the on-grid prices of these projects were announced by the NEA based on the bidding result, ranging from RMB 0.729 per kWh to RMB 0.991 per kWh. As a result, China's Solar PV electricity price has been significantly reduced from RMB 4 per kWh in 2008 to RMB 1 per kWh or less in 2010.

These government incentive programs led to a wave of nationwide enthusiasm for solar PV, and created a surge in China's solar PV market. However, at this stage the burgeoning solar PV market was only considered an experimental phase by the Chinese government, and projects were just for demonstration purposes.

3.5. The national FIT scheme

As the bid prices of the projects under the concession program were much lower than some solar industry participants had expected, energy power companies and private solar equipment suppliers were discouraged from investing in China's solar market. With a dampened financial incentive, project developers in China could barely break even, let alone get a decent investment return. Likewise, Chinese manufacturers have been putting pressure on Chinese government policy makers for better incentives since some European countries—which until 2011 had been the largest customers of Chinese solar panels—drastically cut subsidies for solar power and capped future increases.

It is against this background that in July 2011, the National Development and Reform Commission (NDRC) announced its first nationwide FIT scheme for solar PV development in an effort to boost China's domestic solar industry and to increase the share of solar power in China's energy portfolio. The FIT has been warmly received by project developers and project lenders, and is expected to significantly incentivize the development of China's solar power industry.

According to the new FIT scheme, named *Notice on Perfection of Policy Regarding Feed-in Tariff of Power Generated by Solar PV*: (1) Projects approved prior to July 1, 2011, which have completed construction and have achieved commercial operation prior to December 31, 2011, are entitled to a tariff of RMB 1.15/kWh;

(2) Projects approved after July 1, 2011 or approved prior to that date but cannot be completed before the end of 2011 are entitled to a tariff of RMB 1/kWh. And exceptions have been given to projects located in Tibet, which, under certain circumstances can still receive a FIT of RMB 1.15.

The NDRC's policy makes it clear that the government has the right to make adjustments to the tariff, based on factors such as investment cost changes and technology development. The new FIT policy also provides that solar power projects won via the concession process shall not enjoy a price higher than the FIT. And the previous central government subsidy programs—the Solar Roofs Program and the Golden Sun Demonstration Program will continue to be offered agreed subsidies. The new FIT policy, however, provides that projects enjoying these central government subsidies shall have the same tariff as desulphurized-coal fired power projects, the pricing for which differs by region. For example, Guangdong province has the highest pricing of around RMB 0.50, while Xinjiang autonomous region has the lowest of around RMB 0.25. The NDRC branches at the provincial level will carry out the primary mandates of the policy, the particulars of which are still yet to be promulgated by the local governments [21].

3.6. The 12th Five Year Plan for Renewable Energy Development

On September 12th, 2012, the 12*th Five Year Plan for Renewable Energy Development* (12*th Plan*) was issued by the NEA. The targets of solar power capacity and generation during the 12th FYP period are set at 21 GW and 25 GW respectively. According to the 12th *Plan*, China will promote diverse patterns of solar-power development by integrating intensive exploitation with distributed utilization. It will construct large on-grid photovoltaic power stations and solar power generation projects in Qinghai and Gansu provinces, and the Xinjiang Uygur and Inner Mongolia autonomous regions, which boast abundant solar energy and scattered plots of unutilized land, for the purpose of increasing local supplies of electricity. Meanwhile, it will encourage the central and eastern regions to construct distributed photovoltaic power generation systems linked to local buildings. The *plan* specifies that by the end of 2015, the installed capacity of distributed power generation and large power station should both reach 10 GW. This implies that distributed solar PV power generation should be regarded as an important part of China's future solar PV market application. And the government does not encourage the development of solar PV projects that require long distance electricity transmission in the near future,

In addition, the 12th *Plan* also maps out a systematic way of applying distributed power generation on large scale, and proposes to establish an administration mechanism where distributed solar PV power generation network for private use can be connected with power grid indiscriminately and conveniently. It also emphasizes the importance of mobilizing local government, power grid enterprises and consumers, so as to push forward the development of distributed energy in an all-round way [22].

3.7. Free grid-connection services by the SGCC

Pursuant to the 12*th plan* and in response to the government's call for support to the struggling domestic solar PV industry, the State Grid Corporation of China (SGCC), China's largest State-owned power utility company announced that starting on Nov. 1, 2012, it will provide free connection services for distributed solar PV electricity producers that are located close to customers and with installed capacities of less than 6 MW each. The services cover technological assistance including equipment testing, integration plan development, among others [23].

This is a crucial step in removing obstacles that have contained the development of China's solar industry. Previously the SGCC only connected larger-scale solar power plants, which are mainly concentrated in western areas with sufficient sunlight resources, such as the Xinjiang Uyghur Autonomous Region. The cost of connecting so many distributed solar electricity plants to the grid is much higher because they are scattered everywhere and are too small-scale for maximum efficiency [24].

4. Policy challenges for China's solar PV power development

Although the incentives promulgated or implemented in China demonstrate the determination of the Chinese government to

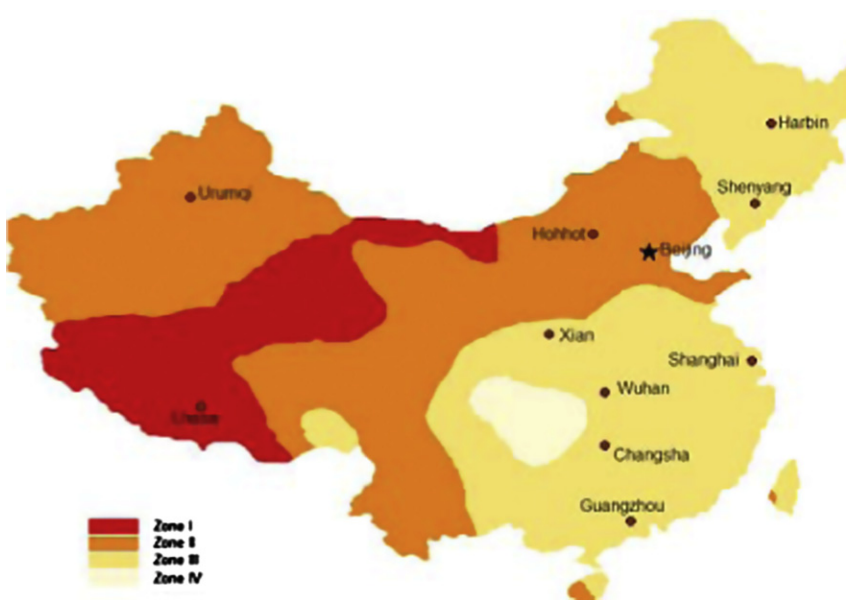


Fig. 6. Solar energy resource distribution in China.
Source: [25]

promote domestic solar PV power market in China, policy challenges do exist. The major barriers for the development of solar PV power currently in China are the deficiencies of the national FIT scheme and the lack of sound technical and administration standards for grid-connection of solar PV systems.

4.1. Deficiencies of the national FIT scheme

The current FIT scheme is far from being effective in that it has three deficiencies: (1) it fails to take the vast regional difference in solar resource and the PV cost variation into account. Although China has abundant solar resources with a daily average radiation of 4 kWh/(m^2/day), the resources are greatly diverse in various areas, ranging from less than 2 kWh/(m^2/day) in parts of the southeast to more than 9 kWh/(m^2/day) in parts of the west, mostly in Zones I and II as shown in Fig. 6 [25]; (2) it provides that solar power projects won via the concession process shall not enjoy a price higher than the FIT. This provision would discourage investors from participating the concession program as no investors would be so silly as to compete for an on-grid price which is lower than the new FIT. As a consequence, the concession program might be brought to its end; (3) it gives no definite period for its implementation.

4.2. Lack of sound state technical and administration standards for the grid-connection of solar PV systems

Although the technology of solar power generation has developed well in China, to date China still lacks sound state technical rules and codes for the grid-connection of solar PV systems, particularly for distributed solar PV systems.

The two state grid-connection rules for solar PV systems—the Technical Rules for Solar PV System Connected to Power Grid (GB/T19939-2005) and the Solar PV System Grid Interface Characteristics (GB/T20046-2006) that are currently in place only provide requirements for the quality of electric power and basic safety for small solar PV stations. There are no requirements for grid planning, safe operation and reliability, inspection standards and management system for grid-connected solar PV systems, among others. In 2011, the SGCC published its Technical Rules for Solar PV System Connected to Power Grid (Q/GDW 617–2011), which, however, is only a company standard and has no compulsory force [26].

5. Policy recommendations

According to PV group,[1] generally speaking, successful solar PV incentives are: (1) sufficient to drive predictable demand. The incentives need to be substantial enough to affect fundamental market transformation, and drive solar PV technology costs down their experience curves; (2) stable and predictable. Policy stability is critical to creating sustained solar PV market growth. Policy must be in place for a long enough period of time to attract investments in manufacturing and the development of a mature industry. Moreover, the "rules of the game" need to be clearly and believably established such that any changes or alterations in the policy can be understood and anticipated ahead of time; (3) transparent and streamlined. Policies should be clearly defined and simple to understand, to allow a broad range of market participants (including individuals) to easily assess risks and make investment decisions; (4) sunset mechanism. Solar PV incentives should be structured with a transition to grid parity in mind. Several of the leading global markets have attempted to achieve this by building steady decreases into their solar PV incentive level in order to both put continual downward pressure on solar PV prices, and to lower policy costs [27]. In light of these norms and China's uniques, we make the following policy recommendations for the expansion of China's domestic solar PV market.

5.1. Construct an effective national FIT scheme

FIT is in place in 61 countries and 26 states/provinces worldwide and has proven to be more effective than other instruments such as investment subsidies, low-interest loans, net metering and fiscal incentives, bidding/tendering schemes in supporting solar PV. In the EU, nearly 100% of the new solar PV capacity since 1997 was installed in countries using FIT and nearly all countries with growing solar PV markets have used FIT [28]. It is recommended that China learn from the best practice in the world as well as draw lessons on its own experience of FIT scheme in the development of wind power.

5.1.1. Learn from the best practice in the world

Germany is the world's strongest solar PV market, with 24.8 GW of cumulative installation in 2011, equivalent to 35.6 percent share of the world market. The grid parity in Germany has been reached at the end of 2012, which means that solar power will then be generated at costs corresponding to those of regular consumer electricity tariff or lower [29]. The main mechanism employed by Germany is the FIT, which is regarded as a valuable mode for policy-makers worldwide. In 2008, the German utilities paid a tariff between €0.35/kWh and €0.47/kWh (depending on the size and type of system) for solar electricity from newly-installed solar PV arrays. The utilities are authorized to pass on this extra cost, spread equally, to all electricity consumers through their electricity bill. This means that the FIT program works through market incentives independent of government budgets and subsidies. In addition, the FIT guaranteed by law over a sufficient period of time (20 years) has proven to be an excellent support for private financing. While being unfamiliar at first, currently the financing of solar PV systems via bank loans in Germany is no longer an unusual and time-consuming activity.

Another important feature of German FIT scheme is a corridor mechanism that regulates the FIT based on market development over the previous period. If the growth of the solar PV market (new installations) in a year is stronger or weaker than the defined growth corridor, FIT will be adjusted up or down the following year. The amount of the adjustment equals the percentage that the threshold was exceeded (or not met), but only for newly-installed solar PV systems. Once a solar PV system is connected to the grid, the tariff remains constant over the complete period of 20 years. This allows solar customers to easily calculate the return on investment in their solar PV systems, while ensuring the industry to continuously reduce costs to main the market [10,30–31].

5.1.2. Draw lessons on the experience of China's FIT scheme for wind power

China's wind power has seen a dramatic development over the period 2005–2011, due to the government's incentives including FIT scheme which is gradually maturing. This FIT scheme can be used as a model for the design of FIT scheme for the solar PV market. China had previously implemented the tariff-setting practice of "concession tendering plus guiding prices" in wind power market. However, this practice which involved complex and time-consuming approval procedures had been evidenced as

[1] PV group represents SEMI (Semiconductor Equipment and Materials Institute) member companies involved in the solar energy manufacturing supply chain.

not best suit the needs of the wind power industry. Since August 2009, China began to implement a four-category, fixed FIT for new onshore wind power projects. The regions with the richest wind resources in the north, northeast and northwest west have been given a tariff of RMB 0.51/kWh, RMB 0.54/kWh and RMB 0.58/kWh, respectively; and the region with relatively less wind resources, central China, was given a tariff of RMB 0.61/kWh. This FIT scheme represented a significant premium for wind power generation over coal-fired electricity generators and has further stimulated developers' interests in wind farm investment [32].

It is recommended that the government adopt differentiated FIT based on regional resource difference, as in the case of China's wind power, and an in-depth research on the FIT standards and feasibility be conducted so as to construct a government support system that best fits China's unique situations [33].

5.2. Impose renewable portfolio standards (RPS)

China's *Medium- and Long-term Renewable Development Plan* (2007) has stipulated the responsibility of power generation companies which have more than 5000 MW generation capacities to contribute 3% and 8% of their generation capacity to non-hydro renewable energy sources by 2010 and 2020, respectively. Due to the mandatory timelines and proportion commitments and the fact that solar PV power cost is much higher than that of wind power, large power generation companies have been induced to increase wind power capacity growth [34]. In contrast, less investment has gone to solar PV power.

As a consequence, over the period from 2006 to 2010, wind power has developed at a spectacular growth rate in China, with a cumulative installed capacity of 44.7 GW in 2010, representing a share of 23% of the global total while solar PV power has developed very slowly, with a cumulative installed capacity of only 800 MW in 2010, representing only 2.94% of the global total. This has resulted in the phenomenon that on the one hand excessive wind power growth has led to about 30% of China's total installed capacity being unable to get access to the grid in 2010 [35], on the other hand sluggish domestic solar PV market has led to the industry's over-dependence on overseas market, from which trade disputes between China and its major trading partners such as the USA and the EU countries arise.

RPS has been instrumental in driving solar PV markets, especially in the USA. It is recommended that China impose mandatory quota on renewable energy power generation, with specific quota for solar PV. The quota could be applied to the grid operation, requiring them to purchase a certain percentage of solar PV power, or applied directly to power companies, requiring them to generate certain percentage of power from solar PV.

5.3. Establish state-level technical and administration standards for the grid-connection of solar PV systems

The high variability of the solar energy source greatly impacts the frequency control, voltage regulation, power supply quality, fault level and stability of the power grid, which is a concern of the utility facing higher penetration of solar PV power. As such, it is crucial to establish state-level technical rules and administration standards for the grid-connection of solar PV projects. In this respect, the Chinese government should also draw lessons on its wind power development. As previously noted, in recent years, China has taken big stride in increasing the country's wind capacity, but the wind industry is facing tough challenges. Most wind farms are struggling to make a profit and about a quarter of installed capacities are not connected to the grid, mostly due to technical difficulties with grid connection, lack of experience in grid operation, and lack of standardization. China did not have a national standard on wind power grid integration until December 30, 2011 when the first state-level standards—*The Wind Farm Connecting Power Systems Technical Regulations* were formally approved by the National Standards Committee and took effect on June 1, 2012.

It is recommended that establishment of state technical and administration standards be expedited through the joint efforts of grid utilities, administrators and solar PV industry [26].

6. Concluding remarks

While policy challenges need to be addressed, it is believed that China has bright prospects of growth in solar PV power development for three main reasons:

Firstly, as the biggest energy consumers and largest emitter of greenhouse gases, China faces a great pressure of developing renewable energy. Coal consumption plays a central role in China's economy. Seventy percent of China's energy consumption comes from coal, much higher than the global average. In the 2008 edition of the International Energy Outlook, the Energy Information Administration (IEA) predicts that in 2030, China will generate more than half of the world's total carbon dioxide emissions from coal use. Coal burning creates a negative impact on China's environment and generates massive amounts of carbon dioxide. Given China's low per-capita energy usage and continued economic expansion, the growth prospects of China's energy demand remain very strong. IEA predicts that China will see the biggest increase in electricity demand and generation capacities among all nations [36].

Secondly, PV powered system enjoys unique benefits and China has its unique advantages for developing solar PV. All renewable energy sources are crucial for China to increase its non-fossil generation capacities, but solar PV powered system will play a critical role. Solar PV systems offer its unique benefits in that (1) solar PV systems can be developed anywhere on suitable land and on buildings; (2) solar PV systems are also modular, a unique characteristic that offers the flexibility to scale up and down; (3) solar PV systems can be installed close to demand centers and their peak production coincides with peak electricity demand; (4) as conventional fuel prices rise and solar PV prices fall, generation costs of solar PV is expected to reach parity in the near future. In addition, China has some unique advantages for developing solar PV because more than half of China's land is located in rich or very rich solar resource areas and offers tremendous opportunity for solar PV power generation; and China has already become the world's leader in solar PV manufacturing and holds a huge yet-to-be-opened domestic market for solar PV.

Finally, but most importantly, the Chinese government is now fully aware of the importance of making full use of solar PV power potential in China. This is reflected by the latest executive meeting of the State Council chaired by China's Premier Wen Jiabao on December 19th, 2012. The State Council emphasized that solar PV is a new strategic industry, and that developing the PV industry is crucial to adjusting the country's energy structure, promoting a revolution in energy production and methods of consumption, and advancing ecological construction. In addition, the meeting confirmed several policy measures. These include accelerating industry restructuring and advancements in technology, considering power grid integration in the planing of PV generation, expanding domestic PV market through the introduction of supporting policies with regional benchmarks for on-grid prices, refining preferential policies for central government's PV financing and fully utilizing market mechanisms to minimize government interference [37].

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